JOURNAL
OF THE
WASHINGTON ACADEMY OF SCIENCES

VOL. 22 APRIL 19, 1932 No. 8

PHYSICS.—*The determination of the electrical units by mechanical measurements.*[1]

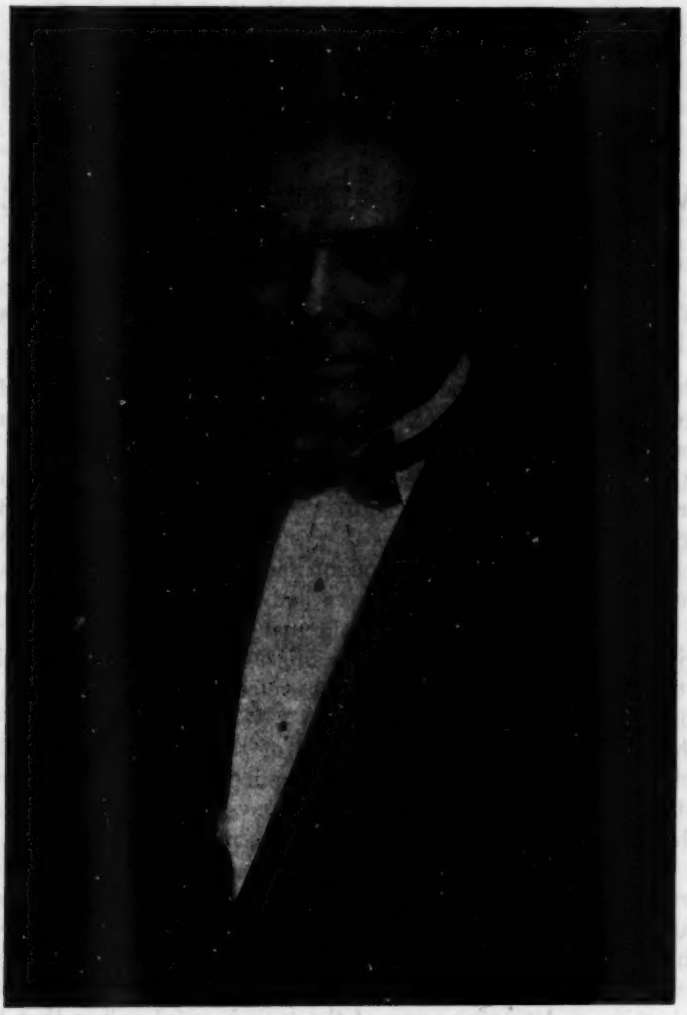
HARVEY L. CURTIS, Bureau of Standards.

The Philosophical Society entrusts the preparation of most of its programs to its Committee on Communications. However, it may be said that the Society as a whole decides on the program for one meeting per year; for in selecting a president, the Society virtually determines the subject for the address, the following year, of the retiring president. Custom requires that this address be on a subject to which the speaker has given thought and attention over a period of years, and very few presidents have had more than one, or at most two, lines of endeavor which would make a suitable subject for a retiring address. Hence a year ago any one of you could have given the title of tonight's address. You have selected the subject; I will supply the treatment.

The electrical units are now a part of the c.g.s. system of units which form a practically complete and unified system for the measurement of all physical quantities. This system, except as regards mechanical units, is definitely based on the principle of the conservation of energy. As this principle was not accepted until the second quarter of the nineteenth century, a unified system of measurement has only been possible during the last hundred years. I shall attempt to show the relationship of the electrical units to the mechanical units, indicate the principles that can be employed in establishing the electrical units, and to give some of the experimental values that have been obtained. I will also give some of the historical settings.

In 1832, just one hundred years ago, was announced the first absolute measurement of an electric or magnetic quantity. In that year

[1] Received February 25, 1932. Address of the retiring president, delivered before the Philosophical Society of Washington, January 16, 1932.



HARVEY L. CURTIS
President, Philosophical Society of Washington
1931

Gauss delivered before the Royal Society of Göttingen a paper entitled *Intensitas vis magneticae terrestris ad mensuram absolutem revocata*. In this paper was described a method for determining the horizontal component of the earth's magnetic field in terms of length, mass, and time. Gauss called this an *absolute* measurement, a name which is still applied when any electric or magnetic quantity is measered in terms of mechanical units. The method of Gauss is still used as a means of measuring the earth's field; in fact, it has been the most widely used method until the last decade.

Following the work of Gauss, physicists developed absolute methods for the measurement of various electrical and magnetic quantities. However, it was not till 1851 that Wilhelm Weber showed that all the electrical and magnetic units can be derived from the mechanical units, thus forming a complete system. In this monumental work, Weber not only showed the possibility of a complete electromagnetic system of units, but outlined methods for making the measurements and actually gave some experimental values for the unit of resistance. This work of Weber's marks the real beginning of absolute electrical measurements. It appeared about seven years after the opening of the first telegraph line, the first commercial application which was made of electric currents. Telegraph engineers soon began to demand suitable units by which to make electrical measurements. This demand was an important factor in establishing the units which are used today.

In order to obtain a fair perspective, let us consider the state of electrical measurements and electrical units in the decade between 1850 and 1860. At this time the only source of a continuous electric current was a primary cell. As the electromotive forces of the different kinds of primary cells are all of the same order of magnitude, no great need was felt for a method of measuring electromotive force. Results could be stated with sufficient accuracy by stating the number of cells in the circuit. The current in a circuit was either measured by a tangent galvanometer or computed by Ohm's law from the electromotive force and resistance. Hence the important requirement was a unit of resistance. During the decade under consideration two different units were extensively used. The first, proposed by Jacobi, consisted of a copper wire of a given length and diameter, the expectation being that any laboratory could construct its own standards. However, the copper of those days varied greatly in resistivity, so that laboratories found it necessary to exchange standards, if they were to be on the same basis.

The second resistance unit, proposed by Siemens, consisted of a filament of mercury having a cross-section of 1 sq. mm. and a length of one meter. This unit was far superior to any that had been previously proposed, and is the forerunner of our present international ohm. No need was felt for standards of capacitance or inductance.

The electrical instruments and methods available during the decade following 1850 were not numerous. The tangent galvanometer was available at the opening of the decade, and Thompson's astatic galvanometer became available soon thereafter. These instruments did not then exhibit the cranky behavior which is the one feature remembered by those in this audience who have used them. There are two reasons why their early behavior was more satisfactory than that of later years. In the first place the sensitivity required was not great; in the second place there were no magnetic disturbances from commercial electrical circuits and electric machinery. At the beginning of the decade, the Wheatstone bridge was available as a means of comparing resistances. This is the one method of that day which still finds favor in our laboratories.

With this background, let us consider the advances which took place in the decade beginning with 1860; a decade in which our present system of electrical units was founded. In 1861, the British Association for the Advancement of Science appointed a Committee on Standards of Electrical Resistance. The Committee in its first report state that before they decided upon a unit of resistance, it would be necessary to decide upon a system of units for the measurement of all electrical quantities. After much discussion and after inviting comments from the leading physicists of the world, including our own Professor Henry, the committee decided upon the c.g.s. electromagnetic system of units as proposed by Weber. At the same time the committee inaugurated experiments to determine the value which should be assigned to the new unit of resistance. In 1863 the B.A. unit of resistance was definitely established as, within experimental error, equal to one billion c.g.s. electromagnetic units.

The B.A. committee made their unit as near the absolute unit as could be determined by their experimental apparatus. However, they did not consider the exact value of the unit nearly as important as the stability of their standard. They expected their unit to remain the standard for an indefinite period and discouraged any further absolute determinations. As a matter of fact, the B.A. unit was extensively used for a quarter of a century.

The B.A. committee gave some attention to the question of a unit of capacitance, which was of some commercial importance at that time in connection with submarine cables. However, no decision was reached. The important contributions of this committee were the c.g.s. electromagnetic system of electrical units and the B.A. ohm.

During the decade beginning in 1870, there was little progress in electrical units. Professor Rowland at Baltimore showed in 1878 that the B.A. unit of resistance was in error by more than one per cent, thus opening the way for the activity that followed.

In the decade that began in 1880, there was a very great increase in all activities which centered around electrical phenomena. Electric generators and motors reached a state of perfection where commercial applications were feasible. Electric lamps passed the experimental stage and furnished an outlet for the power of the "new-fangled dynamo." The telephone became an accepted means of communication. This activity in the commercial field naturally led to greater consideration of electrical units. A series of international conferences was held in Paris, at which names were given to the units, and the importance of deciding on values that agree with the absolute system was emphasized. While the values which were adopted for the units at these conferences were never extensively used, so that the direct results were small, yet the indirect results were outstanding. An important result was the stimulation of research on the units.

The next important action in regard to the electrical units was taken at the Chicago Electrical Congress of 1893, which adopted the International Electrical Units, the legal units in all civilized countries to this day. The International Electrical Units were made more definite at the London Electrical Conference in 1908, and the recommendations of this Conference were made effective by the experimental results obtained at Washington in 1910 by an international committee.

Finally, in 1927, the International Committee on Weights and Measures, to whom due authority had been given by a treaty signed by practically all civilized nations, decided that the absolute system should be adopted as the fundamental system, with material standards approximating as nearly as possible the value of the theoretical unit. All the important standardizing laboratories of the world are now trying to determine the values of their concrete standards in terms of the absolute units.

It is interesting to observe the two different points of view that are held concerning units, and how in the electrical field first one and then

the other has been dominant. One point of view is that, since the units are part of a system, they should conform as nearly as possible to their theoretical value. The other point of view is that, since there is always some experimental error in the value of a derived unit, an arbitrary value should be selected which approximates the correct value, then this arbitrary value maintained indefinitely.

Throughout the history of units, there are many interesting examples of the conflict of these two points of view. In the electrical field, there has been a shifting from one side to the other. The B. A. committee stated that the unit which they had selected was near enough for all practical purposes to the absolute unit, and no farther absolute determinations would ever need to be made. Twenty years later, the Paris Electrical Congress went on record as believing that new values should be established every ten years. Just ten years after this, the Chicago Congress adopted arbitrary standards. And now after nearly forty years more, the pendulum is again swinging back towards absolute units. The underlying causes of these changes in viewpoint are interesting, but time will not permit a discussion of them.

The methods which have been evolved for determining the electrical units of the electromagnetic system from the mechanical units are based on the magnetic effects of the current. The magnetic intensity, **H**, at any point in the neighborhood of an electric circuit, I, can be represented by the equation known as the Biot-Savart Law. This equation is

$$\mathbf{H} = I \int \frac{[\mathbf{r} \times \mathbf{ds}]}{r^3}$$

where **ds** represents an element of the circuit and (**r**) is the distance from **ds** to the point at which the magnetic field is required. This integral shows that the computation of the magnetic intensity for a given current is merely a matter of geometry. Like most geometric problems, it has been accomplished for only a few forms of circuit. In some cases the result is very simple. For instance, the magnetic intensity at the center of a circular loop of radius, R, is

$$\mathbf{H} = \frac{2\pi I}{R}$$

However, at any other point than the center, the value of **H** is expressed as an infinite series.

The electrical unit that follows most directly from the magnetic field of a circuit is the unit of inductance. To show the connection, consider two circuits in one of which there is a varying current having an instantaneous value i_1, and in the other an induced electromotive force e_2 resulting from the variation of i_1. Then, by definition, the mutual inductance between the circuits is given by the equation

$$e_2 = M \frac{\mathrm{d}\, i_1}{\mathrm{d}\, t}$$

Also the induced electromotive force is related to the magnetic flux, φ_2, through the second circuit by the relation

$$e_2 = \frac{\mathrm{d}\, \varphi_2}{\mathrm{d}\, t}$$

Equating and integrating

$$M = \varphi_2 / i_1$$

Hence the mutual inductance is equal to the magnetic flux through the second circuit caused by unit current in the first circuit. But the magnetic flux is the integral, over any surface which is bounded by the second circuit, of the normal component of the magnetic induction. In the electromagnetic system of units the magnetic induction in a vacuum is numerically equal to the magnetic intensity. It follows that φ_2 depends upon i_1 and certain geometric properties of the two circuits. Hence the mutual inductance between two circuits in a vacuum depends only on the geometric properties of the two circuits, although the underlying phenomena are magnetic.

The mutual inductance, M, between any two filamentary circuits which are in a vacuum can be computed by means of Neumann's integral, which is

$$M = \int \frac{\mathrm{d}s_1\, \mathrm{d}s_2 \cos \epsilon}{r}$$

where $\mathrm{d}s_1$ is an element of one circuit, $\mathrm{d}s_2$ an element of the second circuit, ϵ the angle between the directions of the elements, and r the distance between the elements. While this integral contains nothing but geometric quantities, yet the evaluation in any practical case is difficult, and has been accomplished for only a few geometric forms. Moreover, some of these in any practical size give only a very small value of mutual inductance. A form important at the present time is

known as Campbell's absolute mutual inductor. The primary consists of a long solenoid with the center portion omitted. The secondary is a coil of many turns located symmetrically with respect to the solenoid, and of considerably greater diameter. The diameter of the secondary is so chosen that its exact value is not important. The important measurements are the diameter, length, and pitch of the winding on the solenoid. The National Physical Laboratory of England has measured three inductors of this type, each designed to have an inductance of about 10,000 microhenrys. Assuming one of these to be correct, the maximum difference between the measured and computed values of the other two was 0.1 microhenry, or ten parts in a million. Hence the Campbell type of mutual inductor can be constructed with sufficient accuracy to give a very precise value of the computed inductance.

The self inductance of a circuit cannot be expressed by an integral as simple as Neumann's integral for mutual inductance. The reason for this is that in a mutual inductance, the circuit can usually be considered as concentrated in a filament, whereas in a self inductance, the finite cross-section of the circuit must be considered. One method of obtaining a suitable integral for expressing the self inductance of a circuit is to consider the circuit divided into an infinite number of filaments of infinitesimal cross-section. Now the position of any two filaments can be expressed in terms of coordinates which are applicable to a cross-section, and the mutual inductance between these two filaments determined by Neumann's formula. Then the average value of the mutual inductance between one filament and all the others can be determined by integration over the cross-sectional area and dividing by the area. Finally the mutual inductance between the average filament and all the other filaments of the cross-section can be determined by again integrating over the cross-sectional area and dividing by the area. This final average mutual inductance is the self inductance of the circuit. To express this as an integral let L be the self inductance of a circuit having a cross-section S in which any elements of the two filaments may be represented by ds_1 and ds_2, then

$$L = \frac{1}{S^2} \iint dS \iint dS \iint \frac{ds_1\, ds_2 \cos \epsilon}{r}$$

where r is the distance between ds_1 and ds_2 and ϵ the angle between their directions. Again this integral involves only geometrical quan-

tities. However its evaluation is so difficult that there are relatively few forms for which the self inductance can be computed.

The one form of self inductor for which the self inductance has a useful value and for which an accurate formula for the self inductance is known is a single layer solenoid. A solenoid can be accurately constructed. Also precision measurements can be made of the diameter of the solenoid, the pitch of the winding, and the diameter of the wire, the three dimensions that are required for computing the inductance. The Bureau of Standards has constructed a solenoid, the inductance of which can, it is believed, be computed with an error of only a few parts in a million. However, no direct check between two similar solenoids has been made.

The inductance of an absolute standard can be computed from measurements of length only, and hence is simpler than any of the other electrical units. These standards are useful not only for establishing working standards of inductance, but as a basis for establishing other electrical units. This latter phase will be discussed as necessity arises.

The electrical unit for which an accurate value is most needed, on which the most effort has been expended, and for which the results have been most unsatisfactory, is the ohm. The number of methods which have been devised for its measurement are numerous. The underlying principle is much the same in all of them. This principle will first be stated, then several applications to specific methods given.

The underlying principle may be stated as determining the ratio of induced electromotive force to current in a circuit where the electromotive force and current can be determined in terms of the same magnetic or electric quantities. Since the same magnetic or electric quantities are used in determining both the current and electromotive force, they will disappear in the ratio, leaving the resistance in terms of mechanical quantities. In order to measure current and electromotive force in the same quantities, it is necessary to assign a numerical value to the ratio of the magnetic intensity and magnetic induction of a vacuum. This value is usually taken as unity, which is equivalent to stating that the permeability of a vacuum is unity.

The underlying principle of the methods for the aboslute measurement of resistance can be illustrated by one of the methods proposed by Wilhelm Weber. Consider a coil having N turns, each of area A, to rotate with an angular velocity, ω, around a vertical axis which passes through a diameter of the coil. The induced electromotive

force, e, at any instant, t, in a place where the horizontal component of the magnetic induction of the earth's field is B, is

$$e = B\,N\,A\,\omega \sin \omega\, t$$

The average value, E, of the electromotive force for a half cycle is, since $\omega = \frac{2\pi}{T}$

$$E = \frac{4B\,N\,A}{T}$$

where T is the period. If this coil is provided with a suitable commutator and connected to a tangent galvanometer, the current through the galvanometer consists of a series of half waves, all the current being in one direction. The average value of this current when measured with a tangent galvanometer having n turns of radius r, at a place where the magnetic intensity of the earth's field is H, is

$$I = \frac{r\,H}{2\,\pi\,n} \tan \theta$$

where θ is the angular deflection of the galvanometer magnet. If the resistance R of the entire circuit is taken as the ratio of the average electromotive force to the average current, then, since P and H are numerically equal,

$$R = \frac{E}{I} = \frac{4B\,N\,A/T}{H\,r \tan \theta/2\,\pi\,n} = \frac{8\,\pi\,n\,N\,A}{T\,r \tan \theta}$$

where T is the time of a revolution of the coil. This equation shows that R is determined in terms of mechanical units. If all the quantities in the equation are expressed in dimensional units, then $[R] = [L/T]$, which is responsible for the statement that a resistance is a velocity.

The above method is not capable of giving results of high accuracy. It has been introduced solely to illustrate the fundamental principles involved in any absolute ohm determination, and to show the type of apparatus used in the earliest experiments.

Another historical method is the combination into a single instrument of the earth inductor and the tangent galvanometer of the preceding method. A magnetic needle is suspended at the center of a coil mounted to rotate about a vertical diameter. As the coil rotates, the magnet is deflected because the earth's field induces a current in

the coil, which in turn produces a magnetic field at the center of the coil that is at right angles to the earth's field. The amount of deflection depends on the diameter of the coil, its velocity and its resistance. This method was independently proposed about 1860 by Wilhelm Weber and by Lord Kelvin. It was first used by Maxwell and his associates to establish the B. A. ohm. Since then it has been used for more accurate determinations, but it is not capable of giving results of the highest precision.

Perhaps the most direct method for the absolute measurement of the ohm is the one proposed by Lorenz about 1870. This method employs a form of homopolar generator with air-cored magnets for generating an electromotive force which is compared with the fall in potential produced by a current in a resistance. The armature of the generator consists of a disc mounted to rotate around its axis. The magnetic field of the generator is produced by a coil, solenoid, or group of coils which are placed with their axes coinciding with the axis of the disc. Then as the disc rotates, the same electromotive force is produced in every radius of the disc. The electromotive force in each radius is equal to the magnetic flux through the disc divided by the time of a revolution. But the flux for unit current in the coils is equal to the mutual inductance, M, between the coils and a circle which coincides with the circumference of the disc. Hence the electromotive force E between the center and the circumference of the disc is given by the equation

$$E = \frac{M\,I}{T}$$

where I is the current in the coils and T is the time of a revolution. This electromotive force is balanced against the drop in potential over a resistance, R, in series with the coils. Hence

$$E = IR = \frac{M\,I}{T}$$

or

$$R = \frac{M}{T}$$

Now the value of M can be computed from measured dimensions of the coil and disc.

The Lorenz method is considered by many as one of the best that

has ever been devised. One difficulty with the method is the very small value of the induced electromotive force, generally, only a few millivolts. At the National Physical Laboratory a determination in 1914 by F. E. Smith gave a result with a probable error of only three parts in a hundred thousand.

While it is not the purpose here to discuss all the various methods that have been proposed and used for absolute ohm determinations, yet the picture would be so incomplete without a mention of alternating current methods that one of these methods will be described. Alternating current measurements have been largely developed since the days when it was fashionable to make absolute ohm determinations. Hence, while a number of alternating current methods have been proposed, only one satisfactory determination has been completed. This determination was made at the Physikalisch-Technische Reichsanstalt of Berlin, although the method was first suggested by Rosa, a former president of this Society.

The Rosa method employs a self inductance, the value of which can be computed from its linear dimensions and can be measured by an alternating current bridge in terms of capacitance and resistance. The capacitance is then measured in terms of resistance and time by Maxwell's method. From these two measurements the resistance of a resistor can be determined in terms of a self inductance, a time, and the ratios of two pairs of resistances. The method assumes that the value of the capacitance is the same when measured by alternating current as when measured by charging and discharging. This assumption holds only when the capacitor has no absorption, a condition that can be met only with an air capacitor.

During the past 80 years about 25 determinations of the absolute value of the ohm have been made. Fortunately it is possible satisfactorily to compare the results of these determinations. About the time of the first absolute determinations, Siemens suggested the use of a mercury column having a cross-section of one sq. mm. and a length of a meter as a unit of resistance. From that time to this, results of absolute determination have been expressed in such a manner that they can be readily reduced to the length of the standard mercury column. In two of the latest results, the errors connected with the mercury column appear to be as large as those of the apparatus for the absolute measurement. In this case, however, an interchange of wire standards was made about the time of the experimental work, so that the relative value is known.

The results of all determinations are shown in Fig. 1. The abscissas are time in years, while the ordinates are length of the standard mercury column in centimeters. This figure shows that the early determinations differed from one another by several per cent. There was a considerable increase in accuracy following 1880. More than half of the determinations were made between 1880 and 1895. During the twentieth century there have been but two satisfactory determinations. These show that the length of the standard mercury

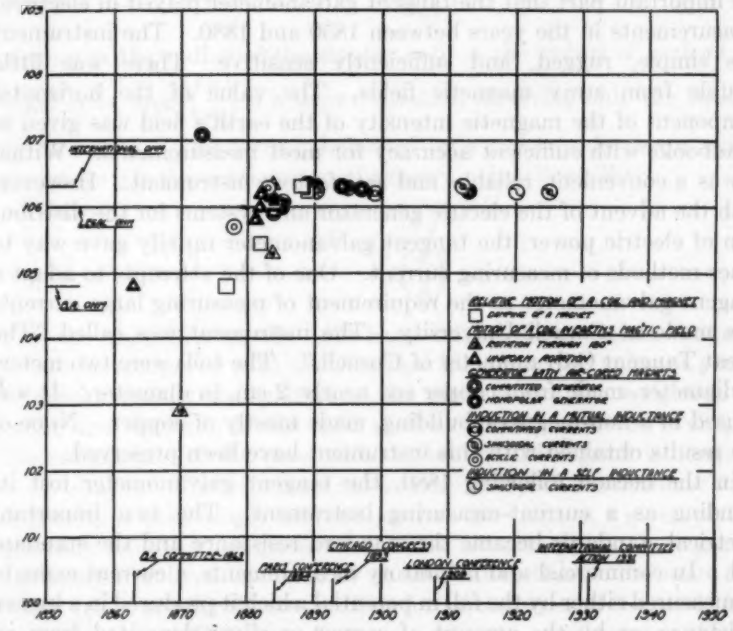


Figure 1.—Length of a column of mercury having a resistance of one ohm as determined at various times and by various methods.

column corresponding to an absolute ohm is about 106.245 cm., whereas the international ohm specifies a length of 106.300 cm. The International Committee of Weights and Measures has decided to abandon the International Ohm in the near future.

The electrical unit which was first determined in terms of mechanical units and which has been most often so measured is the ampere. In fact for more than a quarter of a century most measurements of current were by absolute methods. In 1837, Poulliet devised the

tangent galvanometer which permitted a current to be measured in terms of the deflection of a magnetic needle, the radius of the galvanometer coil, and the horizontal component of the intensity of the earth's magnetic field. As Gauss had previously shown that the intensity of the earth's magnetic field can be measured in terms of mechanical units, the tangent galvanometer permits the absolute measurement of current.

It is difficult for physicists and engineers of today to appreciate the important part that the tangent galvanometer played in electrical measurements in the years between 1850 and 1880. The instrument was simple, rugged, and sufficiently sensitive. There was little trouble from stray magnetic fields. The value of the horizontal component of the magnetic intensity of the earth's field was given in handbooks with sufficient accuracy for most measurements. Withal it was a convenient, reliable, and satisfactory instrument. However, with the advent of the electric generator and systems for the distribution of electric power, the tangent galvanometer rapidly gave way to other methods of measuring current. One of the attempts to adapt a tangent galvanometer to the requirement of measuring large currents was made at Cornell University. The instrument was called "The Great Tangent Galvanometer of Cornell." The coils were two meters in diameter, made from copper rod nearly 2 cm. in diameter. It was housed in a non-magnetic building, made mostly of copper. None of the results obtained with this instrument have been preserved.

In the decade following 1880, the tangent galvanometer lost its standing as a current-measuring instrument. The two important electrical standards became the standard resistance and the standard cell. In commercial and laboratory measurements, a current came to be measured either by the fall in potential which it produced in a known resistance, or by the amount of copper or silver deposited from an electrolytic solution. But to determine initially the electromotive force of a standard cell, or the amount of silver or copper deposited by unit current, some type of absolute current-measuring instrument is necessary. In addition to the tangent and the sine galvanometers, two types of instrument have been used, the current balance and the torsion electrodynamometer.

In a current balance, the force of attraction between two coils through which a current is flowing is balanced against the gravitational attraction of a known mass. Several arrangements of coils have been used. In the one proposed by Lord Rayleigh, a coil of moderate size and relatively few turns is suspended, with its plane horizontal, from

the pan of a balance, flexible leads bringing the current to the coil. Two much larger coils are supported, one above, the other below the moving coil, so that their axes coincide with the axis of the suspended coil and with the distance between the suspended coil and each fixed coil such that when a current is flowing, the force on the suspended coil is a maximum. When the coils are in this position of maximum force, the force of attraction, F, for a current I is

$$F = I^2 f\left(\frac{a}{A}\right)$$

where a is the radius of the smaller coil, A the radius of each of the larger coils, and $f\left(\frac{a}{A}\right)$ is a known function involving only the ratio of the two radii. This force is balanced by a mass, m, having a weight mg, where g is the acceleration of gravity. It follows that

$$I^2 = \frac{m\,g}{f\left(\frac{a}{A}\right)}$$

Of the quantities on the right hand side of the equation, the mass, m, can be compared with the standard kilogram, the value of g must be experimentally determined at the place where the weighings are made, and the ratio of the radii of the two coils must be evaluated. The comparison of the mass with the standard kilogram is comparatively simple. The experimental determination of the absolute value of gravity is exceedingly difficult, so that the value at a given place is generally found by comparison with that at some place where gravity has been carefully determined by an absolute method. For more than thirty years, gravity determinations for all countries of the world have been referred to Potsdam, Germany, where a very careful absolute determination was made during the latter part of the nineteenth century. In comparing gravity at one place with that at another, appreciable errors may enter. One of the largest sources of possible error in recent absolute current determinations has been the uncertainty in the value of gravity.

To determine the ratio of the radius of the small coil to that of one of the large coils, the two coils are mounted concentrically in a vertical plane which is parallel to the horizontal component of the earth's field. At the common center is suspended a small magnetic needle. A current is sent through the small coil producing a deflection of the

magnetic needle. Then a current is sent through the large coil, of such magnitude and direction that the deflection is reduced to zero. Knowing the number of turns on each coil, and measuring the ratio of the currents, the ratio of the radii is given by the equation

$$\frac{a}{A} = \frac{n_1 I_1}{n_2 I_2}$$

Hence measuring the ratio of the radii is reduced to measuring the ratio of two currents, a comparatively simple process.

One difficulty with this method for the absolute measurement of a current is the extreme precision required in the weighing. As an illustration, the suspended coils used by Rosa, Dorsey and Miller all weighed more than a kilogram. The force caused by a reversal of the current was about 5 grams. Hence for an accuracy of one in a million in the current the weighings had to be made to 0.01 mg. For a weight of a kilogram on the balance beam, this means that the balance must be sufficiently sensitive to weigh to a part in a hundred million. Moreover, this weighing must be made with current in the suspended coil, which produces heating and the accompanying air currents.

A torsion electrodynamometer measures, in terms of mechanical units, the torque between two coils carrying a current. This method has often been used, but time prevents a discussion of its principles.

There are two methods by which the result of an absolute current measurement can be preserved; one by determining the electrochemical action in an electrolytic cell, the other by comparing the potential drop produced in a standard resistance with the electromotive force of a standard cell. The first method has been used since the early days of measuring electric currents; the second has been employed in recent absolute determinations. The first is the more useful in comparing results over a long period of years; the second is more valuable for electrical measurements in the laboratory.

Before 1870, the electrolysis of water was frequently used to preserve the results of absolute electrical measurements; it is most unsatisfactory for this purpose. In 1873 Kohlrausch suggested the use of the silver voltameter. Following the Paris Conference of 1881, the silver voltameter was greatly improved and has been extensively employed. Since that time, the results of all important absolute measurements of current either have been expressed in terms of the number of milligrams of silver deposited by a current of one ampere flowing for one second or can be reduced to that basis. These results are shown in Fig. 2. It is interesting to note that the last published result is nearly

twenty years old. The value found, 1.11804 mg. of silver per coulomb, differs by only four parts in a hundred thousand from the value selected by the London Electrical Congress of 1908 for the value of the international ampere: viz., 1.11800 mg/coul.

The value of the absolute volt has usually been obtained as the fall in potential produced by an absolute ampere in an absolute ohm. No absolute measurement in the electromagnetic system has ever been attempted. However it is possible to measure a voltage in electrostatic units, and to convert the result into electromagnetic units by

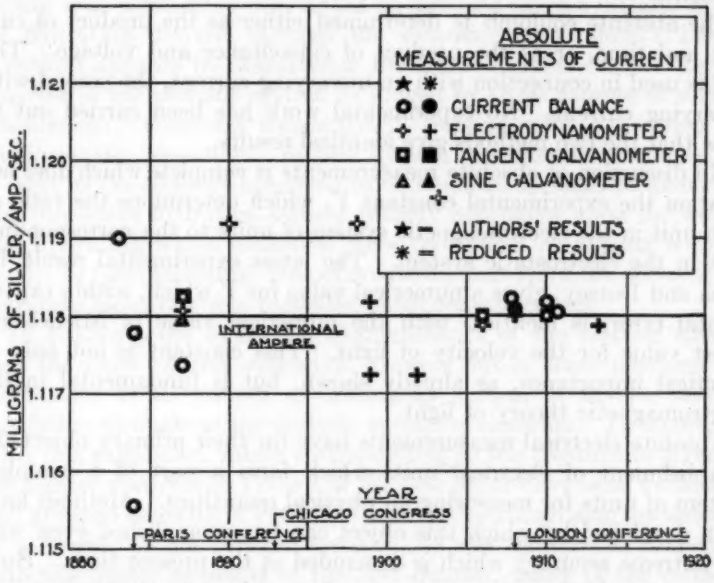


Figure 2.—Rate of deposition of silver by a current of one ampere as determined at various times and by various methods.

means of the experimental constant (usually designated as V, but sometimes as C) which serves to convert from electrostatic to electromagnetic units and vice versa. The method of using an attracted disc electrometer was suggested by Lord Kelvin, but there are no important published results. As the attraction between two discs varies as the square of the potential difference between them, the method requires the use of relatively high voltages.

The determination of a capacitance in absolute microfarads is usually accomplished by reference to other absolute electrical units.

There are three distinct methods of procedure. In the first method a capacitance is compared with an inductance and at least two resistances; in the second, with a resistance and time; in the third, with an inductance and the frequency of an alternating current. No discussion of these methods will be attempted. It is sufficient to note that for most capacitors, the different methods yield different results. When the dielectric of the capacitor is a vacuum or an un-ionized gas, then the three methods give identical results. Only capacitors with such dielectrics are suitable for use in absolute electrical measurements.

The absolute coulomb is determined either as the product of current and time, or as the product of capacitance and voltage. The first is used in connection with an unvarying current, the second with a varying current. No experimental work has been carried out to show that the two methods give identical results.

No discussion of absolute measurements is complete which does not mention the experimental constant V, which determines the ratio of each unit in the electromagnetic system of units to the corresponding unit in the electrostatic system. The latest experimental result, by Rosa and Dorsey, gives a numerical value for V which, within experimental error, is identical with the numerical value of Michelson's latest value for the velocity of light. This constant is not only of practical importance, as already shown, but is fundamental in the electromagnetic theory of light.

Absolute electrical measurements have for their primary object the establishment of electrical units which form a part of a complete system of units for measuring all physical quantities. Methods have been developed by which this object can be accomplished even with the extreme accuracy which is demanded at the present time. However, most absolute measurements of precision are time-consuming, and require very special equipment. Only the national laboratories have the men and facilities for this work. Hence, relatively few new results are to be expected in the immediate future.

In closing I wish to pay tribute to those members and former members of this Society who have made important contributions to absolute electrical measurements. Omitting those who are now active in this field, and who may at any time describe their work to you, one thinks immediately of Rosa, Dorsey, and Grover as men who have in recent years made important contributions. In particular, the late E. B. Rosa, former president of the Society, did much to advance our

knowledge of absolute measurements. However, in choosing a subject for a presidential address, he was considerate of the Society, and decided not to bore them with an address on absolute electrical measurements.

CHEMISTRY.—*The hydration of the solute ions of the heavier elements.*[1] L. H. FLINT. Bureau of Plant Industry. (Communicated by G. N. COLLINS.)

In the first paper[2] of a proposed series dealing with the hydration of solute ions it has been shown that an assumed inverse integral system of hydration derived through the extension of Graham's Law to solutions appears to characterize the stable element-ions of the first quarter of the periodic system as judged by three aspects of solution phenomena,—electrical conductivity, freezing-point depression and boiling-point elevation. In the system as therein developed the weight of the element appeared to be modified incident to ionization; the respective hydration seemed entirely dependent upon the weight; the hydrating water molecules were considered as uniting with the atoms to form molecular ions of solute distinct from the solvent; and complete ionization was indicated at all concentrations.

In studying the hydration characteristics of the heavier element ions the most natural suggestion growing out of these previous considerations is to project an analogous system of inverse integral hydration throughout the periodic system of elements. In accordance with this suggestion values corresponding to the treatments given for the lighter elements in Table 1 of the first paper have been worked out and grouped herewith in Table 1,—each section comprising the elements of a quarter of the periodic system. As was the case in connection with the lighter elements of the first quarter, many of the elements included are not known as stable ions in aqueous solutions. However, since the assumed hydration appears to be conditioned by weight as modified by ionization, the full set of values seems desirable as a reference.

In the above table the assumed hydration in terms of water molecules per ion is given in the fifth column. The calculated weight values for the unhydrated and hydrated states are given in the third and seventh columns respectively, while the velocities corresponding to these weight values are given in the fourth and eighth columns.

[1] Received February 24, 1932.

[2] *The hydration of the solute ions of the lighter elements.* This JOURNAL **22**: 97–119. 1932.

TABLE 1.—WEIGHT, HYDRATION AND VELOCITY VALUES FOR A POSTULATED INVERSE INTEGRAL HYDRATION SYSTEM AS APPLIED TO THE HEAVIER ELEMENTS

A.N.	E	Assumed as W. 2 x A.N.	V_1	Postulated Number of Water Molecules	Mol. Wt. Water of Hydration	Mol. Wt. Hydrated Molecule	V_2
23	V	46	1475	23	414	460	466
24	Cr	48	1443	22	396	444	475
25	Mn	50	1414	21	378	428	484
26	Fe	52	1387	20	360	412	494
27	Co	54	1360	19	342	396	502
28	Ni	56	1336	18	324	380	513
29	Cu	58	1313	17	306	364	524
30	Zn	60	1290	16	288	348	536
31	Ga	62	1270	15	270	332	549
32	Ge	64	1250	14	252	316	563
33	As	66	1230	13	234	300	578
34	Se	68	1212	12	216	284	594
35	Br	70	1195	11	198	268	611
36	Kr	72	1178	10	180	252	630
37	Rb	74	1162	9	162	236	651
38	Sr	76	1147	8	144	220	675
39	Y	78	1132	7	126	204	700
40	Zr	80	1118	6	108	188	729
41	Cb	82	1105	5	90	172	763
42	Mo	84	1091	4	72	156	800
43	Ma	86	1078	3	54	140	846
44	Ru	88	1065	2	36	124	899
45	Rh	90	1054	1	18	108	963
46	Pd	92	1042	0	0	92	1042
46	Pd	92	1042	23	414	506	445
47	Ag	94	1031	22	396	490	452
48	Cd	96	1020	21	378	474	460
49	In	98	1010	20	360	458	467
50	Sn	100	1000	19	342	442	476
51	Sb	102	992	18	324	426	485
52	Te	104	982	17	306	410	494
53	I	106	972	16	288	394	502
54	Xe	108	963	15	270	378	514
55	Cs	110	954	14	252	362	526
56	Ba	112	945	13	234	346	538
57	La	114	936	12	216	330	551
58	Ce	116	929	11	198	314	565
59	Pr	118	922	10	180	298	580
60	Nd	120	914	9	162	282	595
61	Il	122	906	8	144	266	613
62	Sm	124	898	7	126	250	631
63	Eu	126	891	6	108	234	654
64	Gd	128	884	5	90	218	678
65	Tb	130	878	4	72	202	704
66	Dy	132	871	3	54	186	733

TABLE 1.—WEIGHT, HYDRATION AND VELOCITY VALUES FOR A POSTULATED INVERSE INTEGRAL HYDRATION SYSTEM AS APPLIED TO THE HEAVIER ELEMENTS—*Concluded*

A N.	E	Assumed as W. 2 x A.N.	V_1	Postulated Number of Water Molecules	Mol. Wt. Water of Hydration	Mol. Wt. Hydrated Molecule	V_2
67	Ho	134	864	2	36	170	768
68	Er	136	858	1	18	154	806
69	Tm	138	851	0	0	138	851
69	Tm	138	851	23	414	552	426
70	Yb	140	845	22	396	536	432
71	Lu	142	839	21	378	520	439
72	Hf	144	833	20	360	504	445
73	Ta	146	828	19	342	488	453
74	W	148	822	18	324	472	460
75	Re	150	817	17	306	456	468
76	Os	152	811	16	288	440	477
77	Ir	154	806	15	270	424	486
78	Pt	156	801	14	252	408	495
79	Au	158	796	13	234	392	505
80	Hg	160	790	12	216	376	516
81	Tl	162	786	11	198	360	527
82	Pb	164	781	10	180	344	539
83	Bi	166	776	9	162	328	552
84	Po	168	772	8	144	312	566
85		170	768	7	126	296	581
86	Rn	172	763	6	108	280	598
87		174	758	5	90	264	615
88	Ra	176	754	4	72	248	635
89	Ac	178	750	3	54	232	657
90	Th	180	746	2	36	216	680
91	Pa	182	741	1	18	200	707
92	U	184	737	0	0	184	737

The procedure corresponds precisely with that employed in Table 1 of the previous paper, and represents the extension of Graham's Law of the Diffusion of Gases to solute ions considered as of two potential states (1) hydrated and (2) unhydrated.

In examining evidence for the validity of the system as applied to the lighter element ions it was indicated that the apparent rate of decrease in specific molecular electrical conductivity with increasing concentration was subject to interpretation as an index of the rate at which the solvent becomes modified by the hydrating solute. The apparent rate of decrease thus constituted a convenient measure of hydration, and in the present paper this method of inquiry will be used exclusively in the examination of evidence for the validity of the system as applied to the heavier element ions and represented in Table 1.

With regard to the correspondence of the calculated and observed bases it may be noted that the concentrations used in the taking of measurements of electrical conductivity characteristically involve solutions made up to 1000 cc. rather than the 1000 grams involved in prediction. In dilute solutions the volume method is practically identical with the weight method, but in concentrations as great as 1.0 molecular the differences between the two systems are appreciable. When these differences are enhanced by hydration, particularly with ions having a high hydration, the amount of free solvent present in a one-molecular solution based on volume becomes difficult to evaluate with great precision. Then, again, observed measurements involve the use of the observed combining weights of the elements. As previously noted, these depart from the combining weights suggested under the hydration and weight-change hypotheses, and in the heavier elements the departure becomes appreciable. It seems desirable to consider the validity of the suggested hydration before specifically considering the validity of observed combining weights,—but it will be apparent that in view of the divergent weight bases represented in calculated and observed values a further source of discrepancy may be encountered. In general the use of the volume method for calculating concentration effects a dilution from the concentration calculated on the weight basis, while the use of the observed combining weights effects a concentration over the calculated basis. There is thus a tendency for these two factors to compensate each other with respect to the theoretical bases of calculation,—but under the circumstances an approximate agreement between observed and calculated values is all that may reasonably be anticipated, even were the hydration values known to be correct.

In examining observed conductivity measurements with reference to the values suggested in Table 1 we may assume a familiarity with the general treatments described in connection with the consideration of the lighter element-ions in the first paper.

Chromic Chloride, $CrCl_3$. The summation weight representing the solute in a 1.0 molecular solution of chromic chloride, $CrCl_3$, may be derived from Tables 1 of this and the previous paper, as follows:

Cr = 48, Cr^{+++}	= 54, with 19 H_2O,	mol. wt. hyd.	= 396
Cl = 34, Cl^-	= 32, with 7 H_2O,	mol. wt. hyd.	= 158
Cl = 34, Cl^-	= 32, with 7 H_2O,	mol. wt. hyd.	= 158
Cl = 34, Cl^-	= 32, with 7 H_2O,	mol. wt. hyd.	= 158
		Summation wt.	= 870

From this value the relative weight of solvent present may be derived as

$$1000 - 870 = 130, \text{ or } 13\% \text{ solvent}$$

Observed values for the specific molecular conductivity of $CrCl_3$ are available as follows: 1.0 mol. conc., 0°C.[3] = 45.4, .000244 mol. conc., 0°C.[4] = 229.73, 45.4 ÷ 229.73 = .1977 or 19.77%. The observed conductivity at .000488 mol. conc. is 214.48 and a higher value than 229.73 is thus indicated for "zero" concentration. Considering this fact the order of agreement is such as to constitute evidence in substantiation of the postulated system of hydration.

Copper Chloride, $CuCl_2$. The summation weight representing the solute in a 1.0 molecular solution of copper chloride, $CuCl_2$, may be calculated from Tables 1 of this and the previous paper, as follows:

Cu = 58, Cu^{++} = 62,	with 15 H_2O,	mol. wt. hydrated =	332
Cl = 34, Cl^- = 32,	with 7 H_2O,	mol. wt. hydrated =	158
Cl = 34, Cl^- = 32,	with 7 H_2O,	mol. wt. hydrated =	158
		Summation wt. =	648

From this value the relative weight of solvent present may be derived as

$$1000 - 648 = 352, \text{ or } 35.2\% \text{ solvent}$$

Observed values for the conductivity of $CuCl_2$ at 0°C. may be cited as follows:[5] volume = 1.28, conductivity = 59.3; volume .76, conductivity = 48.22; at zero concentration, conductivity = 165.[6] By interpolation, volume at 1.0 = conductivity at 1.0 mol. conc. = 53.3. The relative conductivity may be derived as 53.3 ÷ 165 = .323, or 32.3%. The order of agreement (35.2% as calculated, 32.3% observed) appears to constitute evidence that the Cu^{++} ion in a solution of copper chloride hydrates with 15 molecules of water as suggested by the postulated system.

Strontium Chloride, $SrCl_2$. The summation weight representing the solute in a 1.0 molecular solution of strontium chloride, $SrCl_2$, may be calculated from Tables 1 of this and the previous paper, as follows:

[3] Int. Crit. Tables, Vol. 6.

[4] Jones, H. C., Carn. Inst. Wash. Pub. #170, p. 62.

[5] Jones, H. C. and Getman, F. H. Am. Chem. Jour. 31: 327. 1904.

[6] Jones, H. C. and Bassett, H. P., on the other hand give 120.0 as the value (Carn. Inst. Wash. Publ. #180, p. 73). The use of this value as a base gives a somewhat higher figure than 32.3%.

Sr = 76, Sr^{++} = 80, with 6 H_2O, mol. wt. hydrated = 188
Cl = 34, Cl^- = 32, with 7 H_2O, mol. wt. hydrated = 158
Cl = 34, Cl^- = 32, with 7 H_2O, mol. wt. hydrated = 158
Summation wt. = 504

From this value the relative amount of solvent present may be derived as

$$1000 - 504 = 496, \text{ or } 49.6\% \text{ solvent}$$

Observed values for the conductivity of $SrCl_2$ in aqueous solutions at 0°C., may be cited as follows:[7] 1.0 mol. conc. = 71.23; .000488 mol. conc. = 133.9. The relative value at 1.0 mol. conc. may be derived as

$$71.23 \div 133.9 = .532, \text{ or } 53.2\%$$

The order of agreement (by calculation 49.6%, by observation 53.2%) appears to constitute evidence that the strontium ion, Sr^{++}, hydrates with 6 molecules of water as predicted by the system being tested.

Cadmium Chloride, $CdCl_2$. The summation weight representing the solute in a 1.0 molecular solution of cadmium chloride, $CdCl_2$, may be calculated from Tables 1 of this and the previous paper, as follows:

Cd = 96, Cd^{++} = 100, with 19 H_2O, mol. wt. hydrated = 442
Cl = 34, Cl^- = 32, with 7 H_2O, mol. wt. hydrated = 158
Cl = 34, Cl^- = 32, with 7 H_2O, mol. wt. hydrated = 158
Summation wt. = 758

From this value the relative weight of solvent may be derived as

$$1000 - 758 = 242, \text{ or } 24.2\% \text{ solvent}$$

Observed values for the conductivity of aqueous solutions of cadmium chloride, $CdCl_2$, at 18°C., may be cited as follows:[8] 1.0 mol. conc. = 22.4; .005 mol. conc. = 91. The relative value at 1.0 mol. conc. may be derived as 22.4 ÷ 91 = .246, or 24.6%. The value at "zero" concentration would be somewhat higher than 91, yet the order of agreement (24.2% calculated, 24.6% observed) appears to indicate that in aqueous solutions of cadmium chloride the cadmium ion, Cd^{++}, hydrates with 19 water molecules as suggested by the extension of the hydration system into the third quarter of the periodic system.

There does not appear to be any electrolyte involving a representative element-ion of the group designated in Table 1, which is hydrated and yet soluble to the extent of a 1.0 molecular solution. On

[7] Jones, H. C., Carn. Inst. Wash. For 1.0 mol. conc. Pub. #180, p. 64; for .000488 mol. conc. Pub. #170, p. 39.

[8] Kohlrausch, F. und Holborn, L. *Leitvermögen der Elektrolyte*, p. 161.

this account the consideration of the validity of the tabulated values (except insofar as analogy may be invoked) must be deferred until a subsequent inquiry into the hydration of the nitrate ion, NO_3^-, and other molecular ions.

The order of agreement noted in the foregoing comparisons appears to constitute evidence for the assumed hydration of the involved ions. However, the further extension of the study leads to the suggestion that not all solute ions are hydrated,—a suggestion which will be considered in the next paper of this series.

PALEOBOTANY.—*A new* Drepanolepis *from Alaska.*[1] EDWARD W. BERRY, Johns Hopkins University.

Some years ago I made a preliminary report on a few specimens collected by F. H. Moffit from the northeast quarter of Quadrangle 601, Chitina valley, Alaska. (U. S. Geological Survey localities 7938, 7939, 7940.) One of these is of special interest in that it represents a type of plant hitherto unknown from North America. It may be described as follows:

Drepanolepis reniformis n. sp.

Figure 1.

Lax cone or open strobilus of undetermined length, at least 10 centimeters long and about 1.5 centimeters in diameter. The axis is relatively slender when account is taken of the size and consistency of the appendages, it being not over 2 millimeters in diameter as preserved. The appendages are well spaced and are probably arranged spirally, although this is an assumption based on analogy which the term cone suggests, since the actual specimens are approximately two ranked as preserved in the rock. The essential portion of the appendages is borne on relatively stout and usually slightly recurved peduncles about 1 millimeter in diameter and about 2 millimeters in length, and consist of a round or elliptical body with a marked concavity on either side of the base, which usually results in a marked basal sinus in the outline, which is therefore more or less reniform, and it is this feature which has suggested the specific name. Their length is about 6 millimeters and the maximum width about 7 millimeters. They are at least 2 millimeters in maximum thickness, evenly rounded, and consist of two parts—an inner, evenly rounded, smooth surfaced seed or stone, which is covered with a thick carbonized exterior like a shell or the ligneous testa of a drupe. This outer covering fits the interior object closely and appears to be a completely enclosing envelope. It is flabellately and dichotomously veined, and these veins appear to extend through its thickness, since they are the same on the inner concave and the outer convex surfaces (of different specimens). This outer layer fits closely on the enclosed seed or stone, from which it breaks away in irregular patches.

[1] Received March 10, 1932.

In none of the specimens, of which there are several in the collection, can the two faces of an individual appendage be seen, but it is my impression that the covering layer is a complete envelope and is not of the nature of a cone scale. In Nathorst's account of the Spitzbergen material which he referred to this genus he adds after seed "(or sporogonium)", but there can be no doubt that the Alaska material is not a sporogonium, but a seed or drupe. In the Spitzbergen material the appendages are interpreted as scales, and the seeds (?) are smaller than the scales and located near their bases.

Possibly a new genus should be erected for the Alaska material, but in view of the complete uncertainty regarding its botanical position, and the lack of

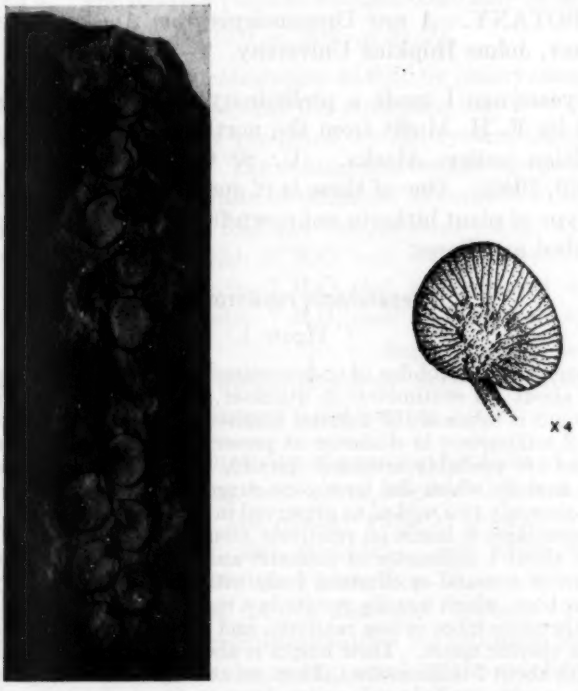


Fig. 1.—*Drepanolepis reniformis:* Photograph of strobilus, natural size, and drawing of a single sporophyll, enlarged.

certainty in the interpretation of the Spitzbergen species as seed-bearing scales, and of that from Alaska as completely enclosed seeds or drupes, it seems unwise to suggest a new genus, especially as the Alaska form agrees with *Drepanolepis* in general habit and size, in stalked appendages containing a rounded more or less inflated seed (or drupe) which is wholly or partially enclosed in a veined envelope.

A great many superficially similar fossil objects have been described from rocks of Jurassic and Lower Cretaceous ages, such as the various species of *Stenorrhachis* Saporta, *Schizolepis* Braun, etc. Some of these objects appear to be definitely cycadaceous, others ginkgoalian, and others uncertain. If the Alaska species has the seeds completely enclosed as suspected, it would be fascinating to consider it angiospermous, although it should not be forgotten that if the whole appendage is a simple seed such a conclusion is not required. In this connection the material under discussion shows a superficial resemblance to the lower Jurassic genera *Caytonia* and *Gristhorpia* in which Thomas[2] has worked out the structure, and for which he has proposed the order Caytoniales, and which he regards as ancient angiosperms.

These two genera differ from the Alaska fossil in having the carpels pinnately arranged on a dorsiventral axis, and these carpels contain many seeds. Indeed, as I understand Thomas's hypothesis[3] of the origin of angiosperms it would be most difficult to conceive of a single seeded carpel in the early stages of the evolution of carpellary structure. On the other hand such a situation is equally difficult in the classic hypothesis of the origin of carpels,[4] or in those advanced in recent years by Vuillemin[5] or Eames.[6]

Nathorst described two species of *Drepanolepis, Drepanolepis angustior*[7] based on *Carpolithes striolatus* Heer[8] which was found in the middle and upper Jurassic of Spitzbergen, and *Drepanolepis rotundifolia*[9] based on *Phyllocladites rotundifolius* Heer[10] which came from the upper Jurassic and the lower Cretaceous of the same region. Probably representing a third species is *Phyllocladites* (?) *morrisi* Cockerell[11] from the Jurassic or Cretaceous Ondai Sair formation of Mongolia. All of these are based upon specimens preserved as impressions and hence not showing structural details, and it is perhaps needless to say that there is no basis for supposing any relationship to the genus *Phyllocladus* which the name might be considered to imply.

In a recent publication[12] devoted to the Upper Cretaceous floras of Alaska Hollick describes and figures what he calls a "bract, phyllode or stipule" under the name of *Phyllocladites dubiosus*, which may or may not be related to what I have called *Drepanolepis reniformis*. It is a single, detached, and

[2] THOMAS, H. S., Phil. Trans. Roy. Soc. London **B 213**: 299–363. 1925.

[3] THOMAS, H. H., Ann. Bot. **45**: 647–672. 1931.

[4] VELENOVSKY, J., *Vergleichende Morphologie der Pflanzen*, Teil 3, 1910.

[5] VUILLEMIN, P., *Les Anomalies végétales*. (Paris, 1926.)

[6] EAMES, A. J., Am. Jour. Bot. **18**: 147–188. 1931.

[7] NATHORST, A. G., Kgl. Svenska Vetens.-Akad. Handl., Band **30**: No. 1, 21, 71, *pl.* 1. *figs.* 16, 17; pl. 3, *figs.* 33–37. 1897.

[8] HEER, O., Fl. Foss. Arct., Band **4**: pt. 1. 47. pl. 9, fig. 17 (lower right). 1877.

[9] NATHORST, A. G., Op. cit. 43. *pl.* 6, *figs.* 24–26. 1897.

[10] HEER, O., Op. cit., Band **3**: ab. 2. 124. pl. 35. *figs.* 17, 18. 1874. Idem, Band **4**: 50. 1877.

[11] COCKERELL, T. D. A., Am. Mus. Nat. Hist. Bull. **51**: 144, tf. 6, *pl.* 2, *figs.* 10, 11. 1924.

[12] HOLLICK, A., U. S. Geol. Survey Prof. Paper 159. 52. *pl.* 2, *fig.* 9. 1930.

apparently a foliaceous organ, veined somewhat like the outer coat in *Drepanolepis reniformis*, but very much larger (about 4 times) and flat, thinner and more delicately veined. I very much doubt any relationship to either *Drepanolepis*, or to what Heer and Cockerell called *Phyllocladites*.

The question of the age of the Alaska material can not be definitely settled. The associated remains are specifically undetermined forms of *Sequoia*, *Podozamites*, *Pterophyllum* and *Sagenopteris*, together with scales and broken fish bones. All the plants belong to long-lived genera the species of which are not precisely determinable, and indicate an age somewhere between middle Jurassic and middle Cretaceous. One of the two *Podozamites* (the larger) appears to be identical with what Lesquereux called *Irites alaskana* from the Cape Lisburne region of Alaska, and which Fontaine referred to *Nageiopsis*, but which I decided did not belong to that genus when I revised it in 1911. The smaller *Podozamites* is much like the Siberian Jurassic form which Heer called *Podozamites eichwaldi* Schimper, but this similarity lacks precise age significance since similar forms under the same or other names occur at a number of Mesozoic horizons. As I interpret the inconclusive evidence as to age it appears more likely to have been late Jurassic rather than early Cretaceous.

In conclusion it should perhaps be mentioned that Thomas, in the papers previously cited, regards *Sagenopteris* as the foliage of the Caytoniales, and *Sagenopteris* is associated with the present fructifications that have been referred to *Drepanolepis*.

GEOLOGY.—*A revision of physical divisions of northern Alabama.*[1] W. D. JOHNSTON JR., U. S. Geological Survey. (Communicated by W. H. BRADLEY.)

In 1930 I proposed a detailed physiographic division of Northern Alabama,[2] based upon Fenneman's[3] classification, which covered that part of the State underlain by Paleozoic sedimentary and older crystalline rocks.

Since the publication of the Alabama paper some disagreement with

[1] Published by permission of the Director, U. S. Geol. Survey and the State Geologist of Alabama. Received March 1, 1932.

[2] JOHNSTON, W. D., JR., *Physical divisions of northern Alabama*. Alabama Geol. Survey, Bull. 38, 1930.

[3] FENNEMAN, N. M., *Physiographic divisions of the United States*, (3d ed.), Assoc. Am. Geographers Annals, 18: no. 4, 1928.

the classification used has been voiced by local geographers and Fenneman[4] has pointed out that the boundary line between the Interior Low Plateaus and the Appalachian Plateaus, adopted for Alabama in

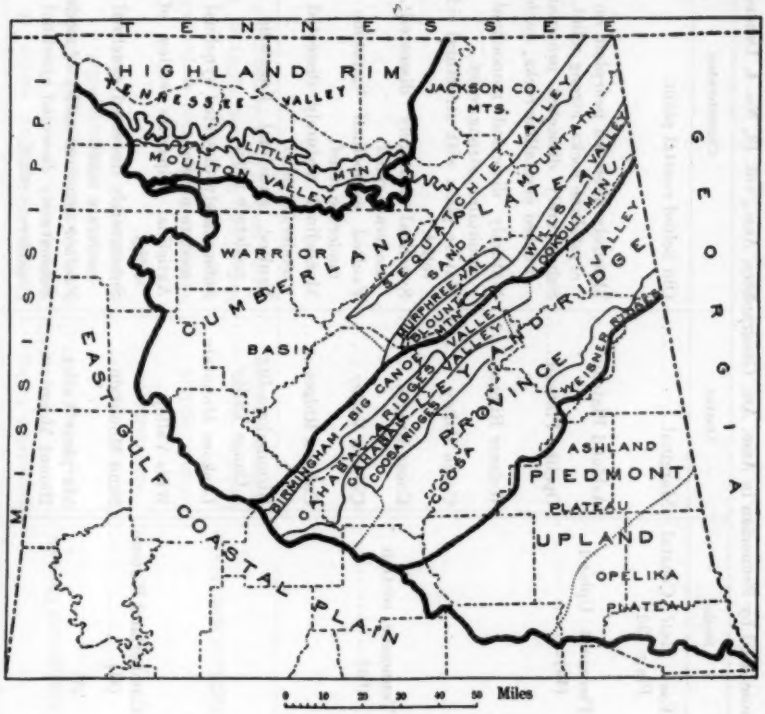


Fig. 1.—Physical divisions of Northern Alabama.

my former publication, is not in agreement with the stratigraphic marker used farther north. To meet these criticisms I offer the revised classification contained in Table 1 and the outline map, Figure 1.

[4] Personal communication.

TABLE 1.—PHYSICAL DIVISIONS OF NORTHERN ALABAMA

Numbers in parentheses correspond with those used by Fenneman in Assc. Am. Geographers, Ann., vol. 18, No. 4, December, 1928

Major Division	Province	Section	District	Characteristics
Atlantic Plain.....	Coastal Plain.....	East Gulf Coastal Plain (3d)	Marginal.....	Old belted coastal plain.
Appalachian Highlands.....	Piedmont Province...	Piedmont Upland (4a).....	Ashland Plateau.....	Maturely dissected peneplain on disordered crystalline rocks; strong relief.
			Opelika Plateau.....	Submaturely dissected peneplain on disordered crystalline rocks; moderate relief
	Valley and Ridge Province.....	Tennessee section (6a).....	Weisner Ridges.....	Maturely dissected monoclinal quartzite mountains; strong relief.
			Coosa Valley.....	Mature plain with structural ridges of low relief.
			Coosa Ridges.....	Synclinal maturely dissected ridges of moderate relief.
			Cahaba Valley.....	Faulted monoclinal limestone valley of moderate relief.
			Cahaba Ridges.....	Monoclinal maturely dissected ridges of moderate relief.
			Birmingham-Big Canoe Valley.....	Faulted anticlinal limestone valley of moderate relief.
	Appalachian Plateaus	Cumberland Plateau (8f).....	Lookout Mountain...	Submaturely dissected synclinal plateau of moderate relief.
			Wills Valley.....	Anticlinal tripartite valley of moderate relief.
			Sand Mountain.....	Submaturely dissected synclinal plateau of moderate relief.
			Murphree Valley.....	Faulted anticlinal valley of moderate relief
			Blount Mountain.....	Submaturely dissected synclinal plateau of moderate relief.

Appalachian Highlands	Appalachian Plateaus	Cumberland Plateau (8f)	Sequatchie Valley	Anticlinal tripartite valley of moderate relief.
			Warrior Basin	Synclinal submaturely to maturely dissected plateau of moderate relief.
			Jackson County Mountains	Submaturely dissected plateau of strong relief.
Interior Plains	Interior Low Plateaus	Highland Rim (11a)	Little Mountain	Submaturely dissected monoclinal ridge of moderate relief.
			Moulton Valley	Monoclinal limestone valley of low relief.
			Tennessee Valley	Young plateau of moderate relief.

BOTANY.—*Arizona plants. (Further additions to the recorded flora of the state, with notes on the characters and geographical distribution of these and others species.)*[1] THOMAS H. KEARNEY and GEORGE J. HARRISON, Bureau of Plant Industry.

A list of flowering plants and ferns believed to be new to the recorded flora of Arizona was published recently.[2] Collections, mostly in 1931, by Robert H. Peebles, Harold J. Fulton, and the writers, and by M. French Gilman,[3] have brought to light several additional species, of which few seem to have been collected previously in Arizona and none, apparently, to have been recorded in any publication as occurring in that state. Six of them were not known to occur in the United States.

Using, with slight modification, the classification of ranges outside Arizona that was followed in the earlier paper (p. 65), the main geographical distributions of these 19 further additions to the recorded flora of Arizona are as follows:

Pacific coast region (Washington to California)	1
California deserts (Colorado, Mojave)	2
Gulf of California region (Lower California, western Sonora)	1
Mexico (not confined to the preceding region) and southward	8
Kansas or Oklahoma to northern Mexico	2
Rocky Mountain region	1
California, eastern United States, tropics of both hemispheres	1
Old World (introduced species)	3

In the following list, species that so far as the writer knows have not been recorded previously as occurring in Arizona are indicated by a single asterisk. Double asterisks indicate that the plant is believed also to be new to the recorded flora of the United States.

The writers are much indebted to Dr. B. L. Robinson of the Gray Herbarium, Harvard University, and to Dr. John K. Small of the New York Botanical Garden for information in regard to the representation of these plants in the respective herbaria.

[1] Received March 6, 1932.

[2] Kearney, Thomas H. Plants new to Arizona. (An annotated list of species added to the recorded flora of the state or otherwise interesting.) Journ. Wash. Acad. Sci. **21**: 63–80. 1931. In explanation of the words "recorded flora" in this subtitle, it should be mentioned that no comprehensive list of Arizona plants has ever been published. If no statement of the occurrence of a given species in Arizona could be found in the various floras and monographs in which its range is stated, or if the range as given in these publications does not comprise Arizona, it was assumed to be new to the known flora of the state.

[3] Plants designated by the large numbers (3592 to 8369, inclusive) were collected by one or more of the first group. Mr. Gilman's specimens are separately designated.

CYPERACEAE

* ELEOCHARIS CARIBAEA (Rottb.) Blake. Collected on Rye Creek, near the eastern base of the Mazatzal Mountains, Gila County (no. 8369). There appears to have been no previous Arizona record of this widely distributed species, but the fact of its occurrence in southern California and in the southeastern United States presupposed its presence in Arizona.

LILIACEAE

CALOCHORTUS FLEXUOSUS Wats. Collected on Rye Creek just east of the Mazatzal Mountains, Gila County, near the center of the state (no. 7804). This collection extends the range considerably southward, the localities in Arizona where this species was previously known to occur being all in the northern part of the state (Grand Canyon, Peach Springs, Beaver Dam).

CLEISTOYUCCA BREVIFOLIA (Engelm.) Rydb. Several hundred good-sized "Joshua Trees" were observed in "bad lands" along the eastern slope of the Aquarius Mountains, near the border between Mohave and Yavapai counties (no. 7633). The occurrence of the plant at this locality had previously been noted by Fred. Gibson of the Boyce Thompson Southwestern Arboretum. It is not, however, the southeastern limit of the species, M. E. Musgrave and S. H. Hastings having found it several years ago at a locality some 30 miles farther south.

ALLIONIACEAE

BOERHAAVIA MEGAPTERA Standley. This well-marked species, known previously only from the vicinity of Tucson, was found at Topawa and at Sells in the Papago Indian Reservation, Pima County (nos. 8027, 8032). The known range was thus extended about 50 miles westward.

PORTULACACEAE

* CLAYTONIA ROSEA Rydb. A collection in the Sierra Ancha, Gila County (no. 7874) marks a considerable southward extension of the known range, Wyoming to Colorado and Utah.

SILENACEAE

* HERNIARIA CINEREA DC. This inconspicuous little plant, an introduction from the Old World, was collected near Casa Grande, Pinal County (no. 7518), and had been found previously by C. R. Orcutt at Sentinel, in the southwestern part of Maricopa County.

SAXIFRAGACEAE

SAXIFRAGA RHOMBOIDEA Greene. Collected in the Mazatzal Mountains and in the Sierra Ancha, Gila County (nos. 7836, 7873). These localities extend the known range some 100 miles southward, the San Francisco Peaks apparently being the only locality in Arizona where the species had been collected previously.

ROSACEAE

PRUNUS FASCICULATA (Torr.) A. Gray. Collected near Wickenburg, in the northwestern part of Maricopa County (no. 7521). It is believed that this locality extends the known range of the "desert almond" in Arizona considerably southeastward.

MIMOSACEAE

* VACHELLIA FARNESIANA (L.) Wight & Arnott (*Acacia farnesiana* Willd.). The occurrence in Arizona of the "huisache" seems not to have been recorded, although it was collected several years ago by David Griffiths at La Osa on the international boundary just east of the Baboquivari Mountains. Trees, some of which attain a height of 20 feet, have been found by W. T. Swingle and R. H. Peebles about 20 miles north of the boundary, at the western base of the Baboquivari Mountains, Pima County.

MIMOSA LAXIFLORA Benth. The occurrence of this Mexican shrub in southern Arizona was noted in an earlier paper (Kearney, ibid., p. 70). Observation during the past season showed it to be abundant near the base of Quijotoa Mountain, Pima County, (nos. 7971, 8001) where it had been discovered by J. Arthur Harris several years ago. Some of the plants at that locality reach a height of more than 6 feet and are very attractive when in blossom. The flowers, clustered in spikelike racemes, are deep purplish-pink at first, fading to nearly white, and have a delicate fragrance. The plant grows on rocky slopes and along "washes," associated with *Anneslia eriophylla*, *Senegalia greggii* (*Acacia greggii*), *Cercidiopsis microphylla* (*Parkinsonia microphylla*), *Acalypha pringlei*, *Jatropha cardiophylla*, *Simmondsia californica*, *Carnegeia gigantea*, and several species of *Opuntia*.

CAESALPINIACEAE

** GRIMALDIA ABSUS (L.) Britton & Rose (*Cassia absus* L.). Found at two stations near "Montezuma's Cave," high up on the western slope of the Baboquivari Mountains, Pima County (*Gilman*, nos. 212 and 234). At one of the stations the plants grew on a ridge of decomposed granite. This is believed to be the first collection of this interesting little annual in Arizona and in the United States. The species is widely distributed in tropical America, but there are no specimens in the U. S. National Herbarium from farther north in Mexico than southern Sinaloa and the states of Jalisco, Morelos, and Vera Cruz. If the plant is really adventive from the Old World, as is supposed, its occurrence in a locality so remote from ordinary lines of communication as the Baboquivari Mountains is most remarkable.

FABACEAE

SOPHORA ARIZONICA Wats. This handsome shrub, with dark green, somewhat shiny leaves and large Wisteria-colored flowers, was found growing on rocky hills and along "washes" some 20 miles southeast of Kingman, Mohave County (no. 7623). The species has a restricted distribution and has seldom been collected, but it was fairly abundant at the locality mentioned. Its beauty makes it as worthy of cultivation as are some of its better known congeners.

PAROSELA LUMHOLTZII (Robinson & Fernald) Vail. This well-marked species, described from specimens obtained by C. V. Hartman at Los Pinitos, Sonora, has been recorded as occurring in Arizona, having been collected near Tucson by Herbert Brown, but apparently it is of rare occurrence in the state. It was collected in 1931 at the base of Baboquivari Peak, Pima County (*Gilman*, no. 241).

SPHINCTOSPERMUM CONSTRICTUM (Wats.) Rose. A collection of this plant on the western slope of the Baboquivari Mountains, Pima County, extends the known range of the species in Arizona some 40 miles to the west (*Gilman*, no. 121).

* ASTRAGALUS AGNINUS Jepson (*Cystium agninum* Rydb.). A handsome milkvetch with showy, reddish-violet flowers, collected in 1927 near the north end of the Gila Mountains in Yuma County, where it occurs abundantly in loose sandy soil (nos. 3592, 5029). This species having been known previously only from the western edge of the Colorado Desert, in California, another plant of that region is added to the recorded flora of Arizona. Professor Jepson wrote to Dr. W. R. Maxon on November 27, 1931, confirming the identification and pointing out only two minor differences between the California and Arizona specimens, the former having the leaflets more deeply notched at apex and the pods more arcuate. The second difference, as Professor Jepson suggests, may be due to the more mature condition of the fruits in the California specimens.

* PHASEOLUS ATROPURPUREUS DC. Collected at a rather high elevation in Fresnal Canyon on the western slope of the Baboquivari Mountains, Pima County (*Gilman*, no. 166). Mr. Gilman describes it as growing in the midst of shrubs that support the stems, which are several feet long. This appears to be the first collection in Arizona,[4] the previously known range of the species being from southern New Mexico and southern Texas to Mexico and Central America. Gilman's specimens are thinner-leafed and less sericeous and have more obtuse leaflets than most of the Mexican and Central American specimens.

EUPHORBIACEAE

CROTON SONORAE Torr. The occurrence of this plant, previously known only from Mexico, in the western part of Pinal County, Arizona, was recorded in an earlier publication (Kearney, ibid., p. 72). During the past season it was collected at Quijotoa and Topawa in the Papago Indian Reservation, Pima County (nos. 7769, 8006, 8026). At the latter locality it grows abundantly on a rocky hill, the shrubs attaining a height and spread of about 4 feet and having stems one-quarter to one-third inch in diameter at base. The form collected at Quijotoa has exceptionally narrow leaves.

DITAXIS BRANDEGEI (Millsp.) Rose & Standl. The presence of this species in the Gila Mountains, Yuma County, was reported in an earlier publication (Kearney, ibid., p. 72). During the past season a plant 6 feet high was observed at the same locality by Robert H. Peebles (no. 7704). Hence, at its northern limit the species attains about the maximum height that it reaches in Lower California and Sonora.[5]

ACALYPHA PRINGLEI Wats. The discovery of this Mexican shrub at Quijotoa, Pima County, Arizona, by J. Arthur Harris, was recorded previously (p. 72). During the past season it was observed growing abundantly at the same locality, along washes and on low rocky hills (nos. 7999, 8000). It is conspicuous during the season of summer rains, because of the vivid green of its foliage. The plants attain a height of only 2 or 3 feet at this locality, and show considerable variation in the size of the leaves and in length and color of the staminate inflorescences. The scales of the latter usually

[4] Specimens collected by T. E. Wilcox (no. 70) near Ft. Huachuca, Cochise County, which are presumably the ones listed under *P. atropurpureus* by Britton and Kearney (Trans. N. Y. Acad. Sci. **14**: 34. 1894) belong to *P. macropoides* Gray.

[5] Standley, Paul C. Trees and Shrubs of Mexico. Contr. U. S. Nat. Herb. **23**: 621. 1923.

are red or reddish. The stamens are white, and the stigmas pale lavender. Some of the associated species are listed in the note on *Mimosa laxiflora*.

RHAMNACEAE

COLUBRINA CALIFORNICA Johnston. The collection of this species by Peebles and Harrison in 1926 in Fish Creek Canyon, Maricopa County (Kearney, ibid., p. 73) was not the first in Arizona, Gilman having found it at the same locality several years earlier. His specimens were identified by J. J. Thornber as "*Colubrina* sp."

MALVACEAE

** ABUTILON THURBERI A. Gray. This species, apparently known previously only from the type collection by George Thurber at Magdalena, Sonora, was collected in a canyon on the western side of the Baboquivari Mountains, Pima County, apparently for the first time in the United States (*Gilman*, no. 35). Gilman's specimen, without fruit, corresponds closely in vegetative and flower characters with the type in the Gray Herbarium, except that the stems are nearly glabrous, whereas in the type they are sparsely villous with long hairs.

HORSFORDIA ALATA (Wats.) A. Gray. The writer, in the earlier paper mentioned (p. 73), erroneously described the petals as of a "pale violet blue" color. R. H. Peebles calls attention to the fact that the color of the fresh petals is pale purplish-pink, although they become bluish with age.

** ANODA CRENATIFLORA Ortega. The finding, in the Chiricahua Mountains, of flowering specimens identified doubtfully as of this species was reported previously (p. 73). During the past season, mature specimens were obtained at Tumacacori, in the valley of the Santa Cruz River (no. 8146), and the characters of the very distinctive fruits remove all doubt as to the identification. The presence of this species in Arizona and in the United States, therefore, is definitely established.

HIBISCUS BISEPTUS Wats. George J. Harrison has noted two characters distinguishing this *Hibiscus* from the somewhat similar *H. coulteri* Harvey, that seem not to have been recorded previously. One is the persistence of the fruits after maturity in *H. biseptus*, whereas in *H. coulteri* the pedicel disarticulates at base. The other character is that in *H. biseptus* the flattened faces of the seeds are devoid of hairs in the center, the hairless area amounting to one-third to one-half the surface of the seed, whereas in *H. coulteri* the hairs are evenly distributed over the whole surface. *Hibiscus coulteri* is a much woodier plant than *H. biseptus*.

APIACEAE

* FOENICULUM VULGARE L. The common fennel of the Old World, although naturalized abundantly in California and sparingly so elsewhere in the United States, seems not to have been reported hitherto as occurring in Arizona. A form with exceptionally short segments of the leaves was collected in the Mule Mountains near Bisbee, Cochise County (no. 8284).

PYROLACEAE

** CHIMAPHILA LASYSTEMMA Torr. This species, known previously only from the mountains of Mexico, was found in the Santa Catalina Mountains, Pima County, at an elevation of about 8,000 feet, growing in clefts of rocks among yellow pines (no. 8100). It flowers in August in this locality and is apparently rare, diligent search having discovered only three individuals.

C. dasystemma bears a marked resemblance to *C. maculata* (L.) Pursh, of the eastern United States, and is regarded by Standley as not specifically distinct from the latter.[6] If this view be correct, the range of *C. maculata* shows a remarkable interruption, similar to that of *Crotalaria sagittalis* and *Clitoria mariana* (Kearney, ibid., pp. 70 and 71).

APOCYNACEAE

AMSONIA KEARNEYANA Woodson. This species, known so far only from the western side of the Baboquivari Mountains in Pima County, Arizona, was regarded by Woodson[7] as representing "a natural hybrid between the subgenera *Sphinctosiphon* and *Articularia*." This conclusion was based partly upon the deformed fruits and sterile seeds of the only fruiting specimen available to Woodson when he wrote his description. Specimens since collected by R. H. Peebles (no. 7933) at or near the type locality have, however, perfectly formed fruits and viable seeds. Mr. Peebles demonstrated this by a germination test in which about 80 per cent of the seeds sprouted. In view of this finding, of the exceptional isolation of the habitat, and of the apparent absence of other species of *Amsonia* in the Baboquivari region, there seems to be little to support the hypothesis of hybrid origin.

CUSCUTACEAE

** CUSCUTA TUBERCULATA Brandegee. This very well-marked species of dodder, known previously only from the southern part of Lower California and from northwestern Sonora (*Pringle*) has been discovered recently in southern Arizona. It occurs rather abundantly along a sandy wash just north of the Gila River, in Pinal County (no. 8193), and has been collected also near Sells, Pima County (no. 8038). The Arizona specimens correspond closely with the type in the herbarium of the University of California, which was collected by T. S. Brandegee on Santa Margarita Island, Lower California. In Arizona, and usually in Lower California, the species is parasitic on species of *Boerhaavia*.

CONVOLVULACEAE

* IPOMAEA HETEROPHYLLA Ortega. The collection near Tombstone, Cochise County, in 1929, of a plant identified as *I. lindheimeri* Gray was reported in an earlier paper (Kearney, ibid., p. 75). Specimens that are similar, except in having the leaf-lobes narrower and more attenuate at both ends, were collected in Fresnal Canyon on the western side of the Baboquivari Mountains, Pima County (*Gilman*, no. 109). All of the Arizona specimens have shorter peduncles and shorter and broader sepals than specimens of *I. lindheimeri* from Texas and New Mexico. As the species of this group are defined by House,[8] the broad bases of the sepals of the Arizona specimens indicate that they belong to *I. heterophylla*, although the corolla is longer and narrower than in most of the Mexican specimens so identified in the U. S. National Herbarium. *I. heterophylla* seems not to have been reported previously as occurring in Arizona. Its range, as given by House, is western Texas and northern Mexico.

[6] Standley, Paul C. Trees and Shrubs of Mexico. Contr. U. S. Nat. Herb. **23**: 1090. 1924.

[7] Woodson, Robert E., Jr. Studies in the Apocynaceae, III. A monograph of the genus *Amsonia*. Ann. Missouri Bot. Garden **15**: 379–434. 1928 (p. 416).

[8] House, Homer D. North American species of the genus *Ipomaea*. Ann. N. Y. Acad. Sci. **18**: 181–263. 1908.

HYDROPHYLLACEAE

* HYDROPHYLLUM OCCIDENTALE A. Gray. The collection of this waterleaf in the Mazatzal Mountains, Gila County (no. 7829), affords apparently the first record of its occurrence in Arizona and extends the known range of the species (Washington to California, Nevada, and Utah) considerably to the southeast.

BORAGINACEAE

* PLAGIOBOTHRYS JONESII Gray. Ivan M. Johnston has identified as of this species a specimen collected near Sacaton, Pinal County, a few miles south of the Gila River (no. 7514), and remarks (in letter to T. H. Kearney): "Known only from at most a score of collections in the eastern part of the Mojave Desert of California. I do not know of a [previous] collection actually from Arizona. Your collection is a big and most interesting eastern extension of this rare and very distinct species."

MENTHACEAE

* SCUTELLARIA DRUMMONDII Benth. The range of this skullcap, as given by Leonard[9] is Oklahoma, New Mexico, Texas, and northeastern Mexico. It occurs also in Arizona, where it was collected along Salt River by Smart, and near Bisbee by Goodding. A third collection, made recently near Roosevelt, Gila County (no. 7778), has been identified by Leonard as *S. drummondii*.

SOLANACEAE

SOLANUM DEFLEXUM Greenman. Collections in southern Arizona of a small-flowered, short-pedicelled form of this chiefly Mexican plant were reported previously (Kearney, ibid., p. 77). A specimen that is normal in size of the corolla and length of the pedicels was collected recently at Tumacacori, Santa Cruz County (no. 8147).

** SOLANUM LUMHOLTZIANUM Bartlett. This well-marked species, belonging to the section *Androcera* (Buffalo burs), was found near Patagonia, Santa Cruz County (no. 8185). The plant seems to have been known previously only from the type collection by C. V. Hartman at La Tinaja, Sonora. The Arizona specimen corresponds closely with the type in the Gray Herbarium and with Bartlett's excellent description, except that the corolla is yellow, not purple, as doubtfully characterized by that author. The narrow, pointed leaf-lobes and the pubescence are very characteristic. Harrison noted in the field that the larger spines of the fruit are black with yellow tips, the small spines of the fruit are greenish white, and the spines on the upper side of the branches are black at base.

* DATURA STRAMONIUM L. Specimens collected at a roadside near the head of Tonto Creek, Gila County (no. 8364), afford what is presumably the first record of occurrence of the common jimson weed in Arizona, unless a specimen in the U. S. National Herbarium, with leaves only, collected in the Chiricahua Mountains by J. C. Blumer (no. 2267), belongs to this species.

SCROPHULARIACEAE

MAURANDYA ACERIFOLIA Pennell. The range of this apparently rare and very local species has been extended ten miles westward of the type locality (Fish Creek Canyon, Maricopa County) to Surprise Canyon, just south of the

[9] Leonard, Emery C. The North American species of *Scutellaria*. Contr. U. S. Nat. Herb. **22**: 703–748. 1927 (p. 730).

Salt River (no. 7774). As at the type locality, the plants were growing in crevices of partly shaded cliffs.

CUCURBITACEAE

* CYCLANTHERA DISSECTA (T. & G.) Arn. This plant, apparently rare in Arizona, was collected in canyons on the western side of the Baboquivari Mountains, Pima County (*Gilman*, no. 198). The only previous collection in Arizona of which the writer is aware was in the Santa Rita Mountains, Pima County, by David Griffiths and J. J. Thornber. Gilman's collection therefore extends the known range of the species about 45 miles westward. The recorded distribution of *C. dissecta* is Kansas to Louisiana, Texas, and northern Mexico. As the species apparently does not occur in New Mexico, this seems to be another case of interrupted range.

ASTERACEAE[10]

ERIGERON PRINGLEI A. Gray. Collected on the rim of Pueblo Canyon in the Sierra Ancha, Gila County (no. 7884). Apparently this species was known previously only from the type collection by Pringle on cliffs of Mt. Wrightson, in the Santa Rita Mountains. In the type collection the lower leaves are laciniate-pinnatifid, whereas in no. 7884 they are very narrowly linear-oblanceolate and entire. Otherwise the specimens correspond exactly and undoubtedly represent the same species.

SENECIO QUERCETORUM Greene. Specimens were obtained on Oak Creek, Coconino County (no. 7160), and on the rim of Pueblo Canyon, in the Sierra Ancha, Gila County (no. 7889). Previously known only from two collections by Rusby, on Oak Creek, the type collection (no. 672), and at an unspecified locality in Arizona (no. 175), the latter being the type of *S. macropus* Greenm. Dr. Greenman, who has referred *S. macropus* to *S. quercetorum*, described the plant as perennial, as Dr. Greene had done, but Fulton's excellent and complete specimen in the U. S. National Herbarium (no. 7160) has a root that is obviously annual or, at most, biennial.

SCIENTIFIC NOTES AND NEWS

Dr. J. BARTELS, who, as a research associate of the Carnegie Institution of Washington, has been engaged on the theoretical interpretation of the accumulated observational date at the Department of Terrestrial Magnetism in Washington, D. C., having completed his year's leave of absence from Germany, has returned to his position in the Forstliche Hochschule in Eberswalde.

The thirteenth annual meetings of the American Geophysical Union and its sections will be held April 28 and 29, 1932, at the National Academy-Research Council Building, 2101 Constitution Avenue, Washington, D.C.

Meetings of scientific societies will be held in Washington as follows: National Academy of Sciences, April 25 and 26; American Physical Society, April 28 to 30; American Section of International Union of Scientific Radiotelegraphy, April 29; American Meterological Society, May 2.

A bill authorizing an appropriation of $30,000 to defray the expenses of participation by the United States Government in the Second Polar Year Program, August 1, 1932, to August 31, 1933, has been passed by Congress and signed by the President.

[10] Identifications and notes communicated by Dr. S. F. Blake.

E. P. KILLIP, Associate Curator of Plants, U. S. National Museum, who left Washington early in February for study in European herbaria, reports very satisfactory results at Berlin. After a month at the Museum d'Histoire Naturelle, Paris, where he now is, Mr. KILLIP will leave for several weeks' work at the Royal Botanic Gardens, Kew, and the British Museum (Natural History), returning to Washington early in May. The work upon which he is engaged, aside from completing monographic studies of several large groups, consists in the identification of extensive series of specimens from the northern Andean region of South America. This material consists partly of specimens collected upon at least a dozen major expeditions, and partly of specimens that have come in during recent years from a large number of institutions and individuals in South America.

HORACE G. RICHARDS has been promoted from Aid to Assistant Curator in the Division of Mollusks, U. S. National Museum.

On Wednesday evening, March 30, in the auditorium of the National Museum, a lecture under the auspices of the Smithsonian Institution on "Plant Records of the Rocks" was presented by ALBERT CHARLES SEWARD, D.Sc., F.R.S., Master of Downing and Professor of Botany, Cambridge University.